DIAGNOSTICS FOR HIGH DENSITY IMPLOSIONS AT THE NATIONAL IGNITION FACILTY

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The proposed National Ignition Facility (NIF) is a large (1.8 MJ on target at 0.35 μm) multi-beam laser facility that will be used for Inertial Confinement Fusion (ICF). ICF implosions at this facility will produce core plasma temperatures over 10 keV and densities over 100 g/cm^3. Properties of these plasmas can be measured by a variety of optical, x-ray and nuclear diagnostic techniques such as those used at existing facilities like the Nova laser. Some of these currently used techniques will be directly applicable to NIF; others, require significant development. Damage of components close to the target will be a much greater issue at NIF, necessitating the development of distant detector techniques. X-ray based core diagnostics will need to utilize substantially higher energies than are in routine use today. Penetrating nuclear particle based diagnostics will be particularly well suited to these implosions and the higher nuclear yields will allow new techniques to be developed. A summary of diagnostics used for high density implosion experiments at Nova[1] will be presented and development of new techniques for NIF will be discussed.

X-ray imaging at Nova is done predominantly with systems requiring components close to the target (e.g., pinholes). In order to allow a larger stand-off distance at NIF and to work at x-ray energies that will penetrate from the core, a high energy (8 keV) x-ray imaging system based on a multi-layer coated Wolter optic is being developed. Using conventional fabrication techniques will result in an unaffordable cost so the use of replica fabrication techniques is being pursued. In this approach a Wolter shaped mandrel is manufactured and coated with the material to be used for the mirror surface. The mandrel surface figure and roughness are critical, but costs are reduced because its exterior surface is accessible compared to the

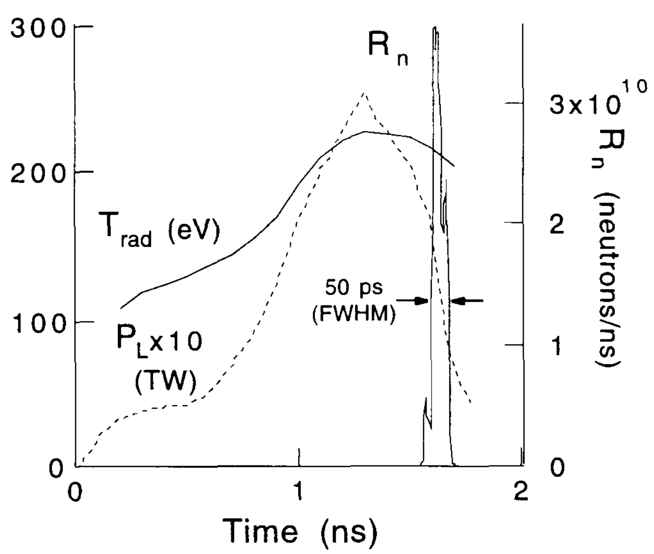

Fig. 1. Neutron reaction history shown relative to laser pulse shape and hohlraum temperature for a high density Nova implosion.

interior surface of a conventionally manufactured Wolter. The mandrel is then coated with a backing material and the whole assembly cooled. Differential contraction is used to break the Wolter mirror surface free from the mandrel. The mandrel can be re-used multiple times.

Fuel density is determined by measuring fuel areal density and inferring the fuel density from simple geometric arguments. The primary diagnostic technique at Nova for the determination of fuel areal density is the measurement of secondary neutrons from pure deuterium fuel. These neutrons, produced in a low yield side reaction, are studied using neutron time-of-flight techniques which allow the determination of both their number and their energy spectrum. Requirements for high sensitivity and high energy resolution necessitated the development of a large neutron spectrometer which is an array of 960 scintillator-photomultiplier tube detectors capable of measuring secondary neutron energy spectra in a single particle mode[2]. A similar technique based on tertiary neutrons can be used for the larger NIF targets.

Fuel ion temperatures are determined by a measurement of the primary neutron energy spectrum, which is broadened by thermal effects that can be related to the plasma temperature. The primary neutron energy spectra are also determined via neutron time-of-flight techniques. Here too, requirements of high sensitivity and high energy resolution have necessitated the development of new instrumentation. Both current mode detectors and another single particle detector array[3] are used at Nova; similar techniques can be used at NIF.

The time at which the neutrons are emitted relative to the laser pulse (burn time) and the yield as a function of time (reaction history) are measured at Nova by a system that utilizes a small scintillator located a few centimeters from the target. The light produced in this scintillator is imaged back to a streak camera, allowing a determination of both quantities. At NIF energies detectors will need to be distant from the target so reaction histories will need to be measured by γ production rate to avoid the loss of time resolution caused by Doppler broadening in neutron based systems. Techniques based on Cerenkov detection of γ rays will be described.

Neutron images of the implosion cores at Nova have been obtained by use of a thick neutron aperture and a penumbral imaging technique. A new system based on this method is currently under development at Nova and should produce images with 20 micron spatial resolution. A similar system is being designed for use at NIF.

New techniques based on charged particle spectroscopy and γ ray spectroscopy will also be presented as well as an overview of expected problems for diagnostics at NIF such as target debris and neutron backgrounds.

ACKNOWLEDGMENT

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

References

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